Tectono-stratigraphic evolution of the Outer Carpathian basins (Western Carpathians, Poland)

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Abstract

In the pre-orogenic and syn-orogenic evolution of the Carpathian basins the following prominent periods can be established: the Late Jurassic/Early Cretaceous subsidence, Late Cretaceous-Paleocene uplift, Paleocene-Middle Eocene subsidence, Late Eocene-Early Oligocene uplift, and Late Oligocene-Early Miocene subsidence. Syn- and post-rift thermal subsidence and accretionary prism migration controlled the depositional processes.

Key words: Outer Carpathians, rifting, inversion, subsidence, tectono-sedimentary evolution

The Outer Carpathians are composed of Upper Jurassic to Lower Miocene flysch deposits, which are completely uprooted from their basement and separated from the Inner Carpathians by the Pieniny Klippen Belt suture zone. The Western Outer Carpathians form an accretionary wedge. Its formation was completed by the Late Oligocene/Middle Miocene. The flysch deposits built up several nappes, subhorizontally overthrust onto the Miocene deposits of the Carpathian Foredeep or directly onto Precambrian, Paleozoic or Mesozoic rocks of the Carpathian foreland. The presented paleotectonic reconstructions are based on the paleotectonic mapping and subsidence modelling of the Polish Outer Carpathians (Fig. 1). The paleotectonic maps have been prepared for several time spans, whereas the burial history has been reconstructed on the basis of 50 selected sections from the Magura, Dukla, Silesian, Subsilesian and Skole units.

Middle Jurassic-Early Cretaceous opening of basins

The Outer Carpathian Basin can be regarded as the remnant ocean basin, which developed between the colliding European continent and the intra-oceanic arcs (Oszczypko, 1999). The Early/Middle Jurassic opening of the Magura Basin probably was coeval with opening of the Ligurian – Penninic Ocean and its supposed prolongation to the Pieniny Ocean (Golonka et al., 2000). The Pieniny Ocean was divided by the submerged Czorsztyn Ridge into the NE and SE arms. The Czorsztyn Ridge and the Inner Carpathian domain were separated by the SE arm of the Pieniny Ocean known also as the Vahicum Oceanic Rift, whereas NE arm was occupied by the Magura deep–sea basin situated south of the European shelf (Fig. 2). During the thrust movements, the main part of the Magura nappe was uprooted roughly at the base of the Upper Cretaceous sequence. The more or less complete sections of the Jurassic-Lower Cretaceous deposits of the Magura nappe are known only from that part of the basin which was incorporated into the Pieniny Klippen Belt, i. e. from the Grajcarek unit (Birkenmajer, 1986). This part of the basin reveals the prominent Late Jurassic, post-rift subsidence which was followed by the Barremian-Aptian uplift and Albian-Cenomanian subsidence (Fig. 3). The Late Jurassic-Early Cretaceous deposits are represented by deep water, condensed, pelagic limestones and radiolarites with very low rate of deposition (Fig. 4). At the end of Jurassic in the southern part of the European shelf, the paleorifts were floored by a thinned continental crust (Birkenmajer, 1988; Sandulescu, 1988). This rifted European margin was incorporated into the Outer Carpathian basin (the Skole, Subsilesian and Silesian basins). The rifting process was accompanied by a volcanic activity (teschenite sills, dykes and local pillow lavas), which persisted up to the end of Hauterivian (Lucińska-Anczkiewicz et al., 2000). This part of the rifted continental margin probably extended in the Eastern Carpathians (basic effusives, Tithonian–Neocomian "Black Flysch" of the Kamyany Potic scale and Rachiv (Sinaia) beds) as well as to the Southern Carpathians (Severin zone, see Sandulescu, 1988). During the initial stage of development, the Silesian Basin was filled with calcareous flysch followed by siliciclastic flysch and pelagic shales. The Late Jurassic–Hauterivian deposition of the Silesian Basin was controlled by normal fault and syn-rift subsidence, and latter (Barremian-Cenomanian) by post-rift thermal subsidence, which culminated with the Albian-Cenomanian expansion of deep-water facies (Figs. 3 and 4).

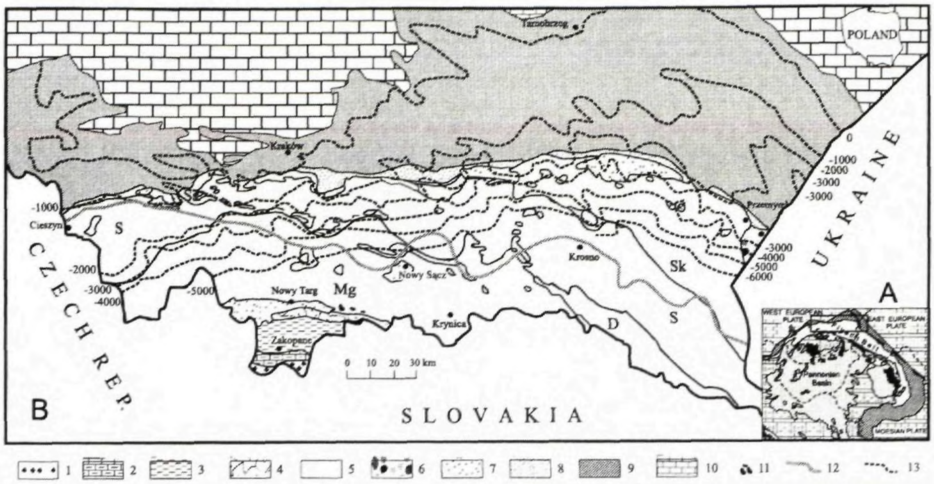

Fig. 1. A – Position of the Polish Carpathians. B – Map of the Polish Carpathians and their foredeep (after Oszczypko, 1998, supplemented). 1 – crystalline core of Tatra Mts., 2 – High-Tatric and Sub-Tatric units, 3 – Podhale Flysch, 4 – Pieniny Klippen Belt, 5 – Outer Carpathians, 6 – Stebnik Unit, 7 – Miocene deposits resting on the Carpathians, 8 – Zgłobice Unit, 9 – Miocene deposits of the Carpathian foredeep, 10 – Mesozoic and Paleozoic foreland deposits, 11 – andesites, 12 – northern range of the Lower Miocene, 13 – isobath of the Miocene basement.

Late Cretaceous-Paleocene inversion and Early/Middle Eocene subsidence

At the end of Turonian, in the central part of the Outer Carpathian domain, the Silesian Ridge (Cordillera) was restructurized and uplifted. The inversion affected most of Silesian, Subsilesian and Skole basins as well as part of the northern periphery of the Magura Basin. The amplitude of the uplift reached several hundreds meters (Fig. 3). The uplift of the Silesian Ridge was accompanied by increase of the deposition rates in the Silesian (up to 400–500 m/Ma; Godula and Istebna formations) Basin (Fig. 4). The uplift of the Silesian Ridge was coeval with regional uplifting in the southern margin of continental Europe from the Carpathian and Alpine foreland to the Spain. This inversion could be correlated with the development of the rift of Biscay Bay (Golonka and Bocharova, 2000). The uplift of the Silesian Ridge could be connected with the shortening of the Silesian Basin (Oszczypko, 1999) and development of the Subsilesian High (Fig. 3). The latter separated Silesian and Skole basins as an elevated high (like peripheral bulge) during the Santonian-Paleocene time. The sedimentation of the pelagic marls with low rate of deposition: dominated in the Subsilesian High area (Fig. 4). The shortening of the Silesian Basin was probably a continuation of the pre-Late Albian subduction of the Outer Dacides (Sandulescu, 1988). At the end of the Paleocene the Carpathian basin was affected by general subsidence and rise of sea level (Fig. 3). During the Eocene, a wide connection of the Outer Carpathian basins and the World Ocean was established. This resulted in unification of facies, including the position of the CCD level and sedimentation rates. This general trend dominated during the Early to Middle Eocene time in the northern basins (Skole, Sub-Silesian, Silesian and Dukla ones) as well as in the northern part of the Magura Basin.

In the Magura Basin the Paleocene–Middle Eocene subsidence was related to the uplift of the Pieniny Klippen Belt (PKB). The migrating load of the Magura and PKB accretionary prism, caused a subsidence and a shift of depocenters to the north (Figs. 2, 3 and 4). As a result, narrow and long submarine fans developed. They were supplied from the southeast, probably from the Median/Inner Dacide terranes. The northern deepest part of the basin, often located below the CCD was dominated by basi-

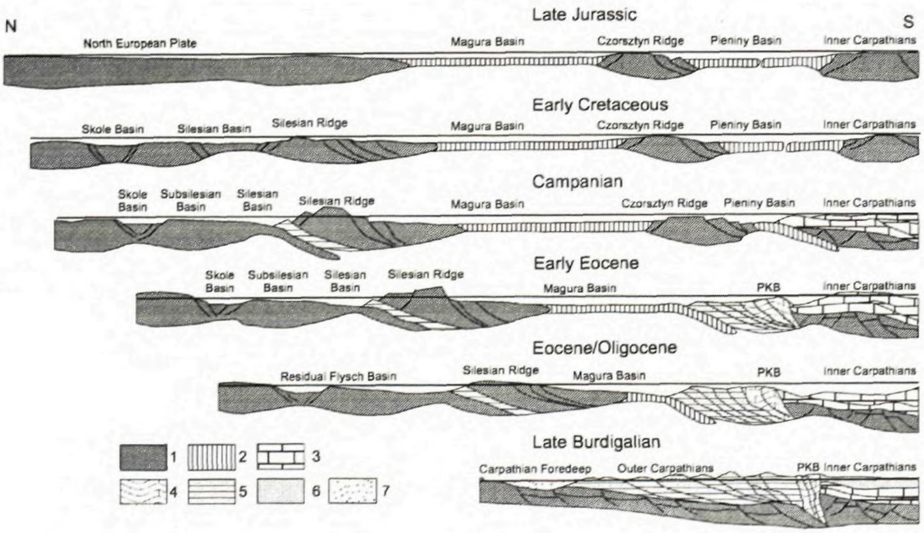

Fig. 2. The Late Jurassic–Late Burdigalian palinspastic evolution model of the Western Outer Carpathians after Oszczypko (1999, supplemented). 1 – continental crust, 2 – oceanic crust, 3 – Inner Carpathian units, 4 – Pieniny Klippen Belt (PKB), 5 – Outer Carpathian accretionary wedge, 6 – Podhale Flysch, 7 – molasse deposits.

nal turbidites and hemipelagites. The rate of sedimentation varied from 6–18 m/Ma on the abyssal plain to 103–160 m/Ma in the outer fan and between 180 and 350m/Ma in the area affected by the middle fan-lobe systems (Oszczypko, 1999). During the Eocene, the axes of subsidence of the Magura Basin migrated towards the north and finally during the Late Eocene and Oligocene reached the Rača and Siary facies zones.

The Late Eocene–Oligocene uplift and Oligocene–Early Miocene subsidence

During the Priabonian and Rupelian, a prominent uplift in the Outer Carpathian basin was recorded (Fig. 3). This was contemporaneous with the final stage of the formation of accretionary wedge in the southern part the Magura Basin (Krynica Zone) and with the main collision phases in the Alpine belt (Fig. 2). This was accompanied by transformation of the Outer Carpathian remnant oceanic basins into foreland basins (Oszczypko, 1999). As the consequence, the Early Oligocene Outer Carpathian basin was partly isolated from the World Ocean, forming the Prototethys, which was dominated by deposition of the black (Menilite) shales. The Oligocene subsidence was accompanied by a progressive migration of axes of depocenters towards the north (Fig. 4), and increase of deposition rates from 350 m/Ma in the Rupelian (northern part of Magura Basin) to 950 m/Ma at the end of Oligocene (SE part of Silesian Basin). After the Late Oligocene folding, the Magura nappe was thrust northwards onto the terminal Krosno flysch basin. This was followed by the last, minor subsidence event (Oligocene-Early Miocene) which can be partially related to the load of accretionary wedge. The centers of subsidence were located in the Krosno basin and Magura piggy-back basin. The restored width of the Early Burdigalian basin probably reached at least 150 km. During the Early Burdigalian high stand of sea level, the connection between Magura piggy-back basin and the Vienna Basin via Orava was established (Oszczypko et al., 1999; Oszczypko-Clowes, 2001). During Ottnangian, the Krosno flysch basin shifted towards NE (Zdanice Unit, Boryslav-Pokuttya and Marginal Fold units) and underwent desiccation (evaporates of the Vorotysche Formation in the Ukraine and Salt Formation in Romania).

The Outer Carpathian residual Krosno flysch basin was finally closed by intra-Burdigalian folding and uplifting of the Outer Carpathians, connected with the collision between the European Plate and overriding Alcapa and Tisza-Dacia microplates. This was accompanied by the north and north-east overthrust and the formation of the flexural depression of the Carpathian Foredeep - related to the moving orogenic front (Oszczypko, 1998).

Conclusions

1. In the pre-orogenic and syn-orogenic evolution of the Outer Carpathian domain the following main tectonic events took place: the Late Jurassic–Early Cretaceous subsidence, Late Cretaceous–Paleocene uplift, Paleocene--Middle Eocene subsidence, Late Eocene-Early Oligocene uplift, and Late Oligocene-Early Miocene subsidence. The

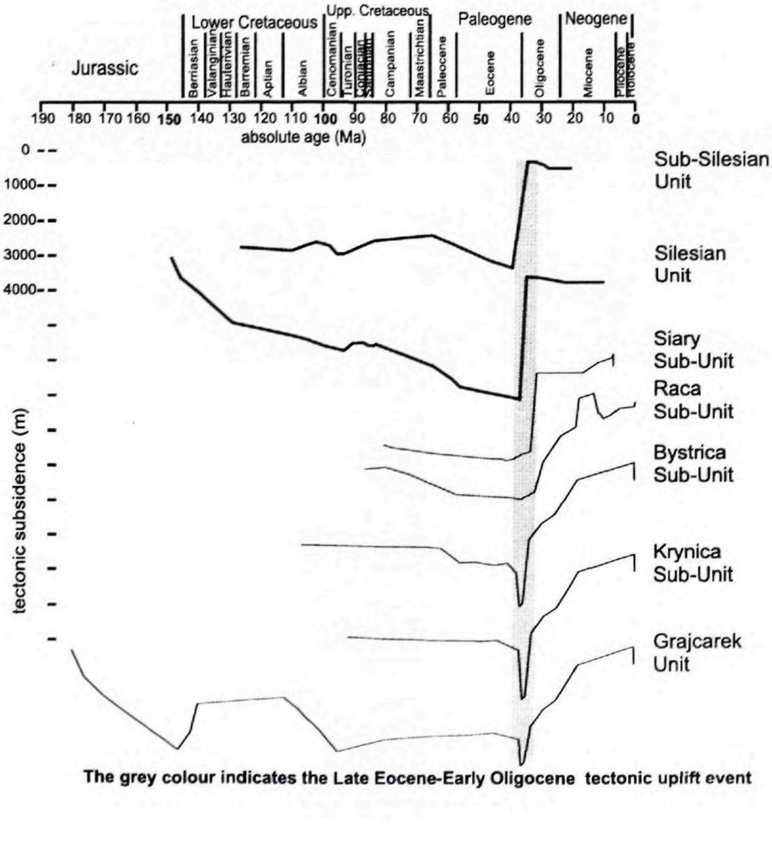

Fig. 3. Tectonic subsidence curves for selected synthetic profiles from the Polish Outer Carpathians.

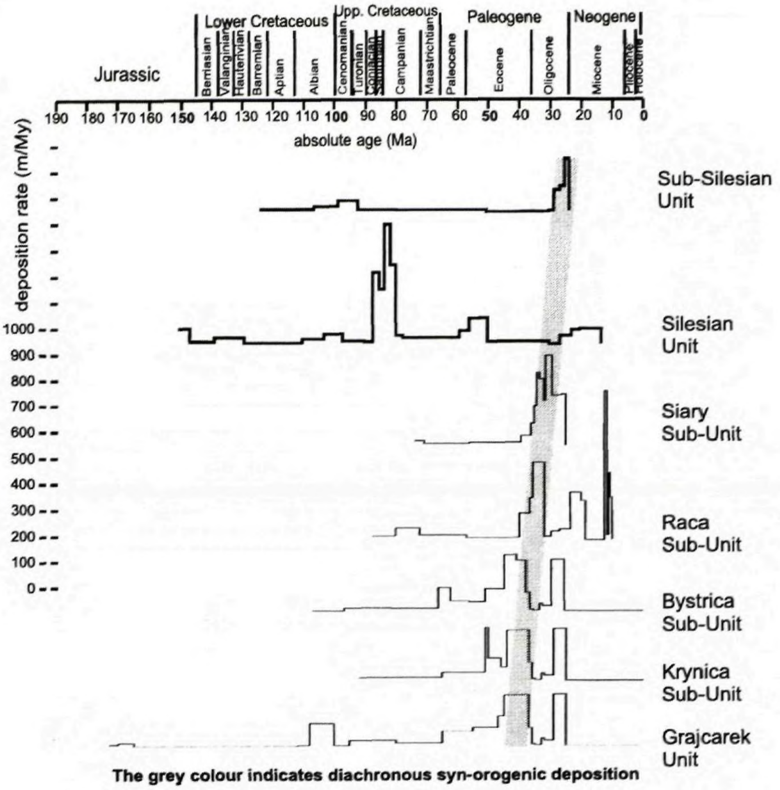

Fig. 4. Diagrams of deposition rates versus time for synthetic profiles from the Polish Outer Carpathians.

total subsidence in the Silesian Basin was two times higher than in the Magura Basin and more than three times higher than in Subsilesian and Skole basins.

2. The important driving forces of the tectonic subsidence were syn-and post-rift thermal processes as well as the emplacement of the nappe loads related to the subduction processes.

3. Similarly to the other orogenic belts, the Outer Carpathians were progressively folded towards the continental margin. This process was initiated at the end of the Paleocene at the PKB/Magura Basin boundary and completed during the Early Burdigalian in the northern part the Krosno flysch basin.

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